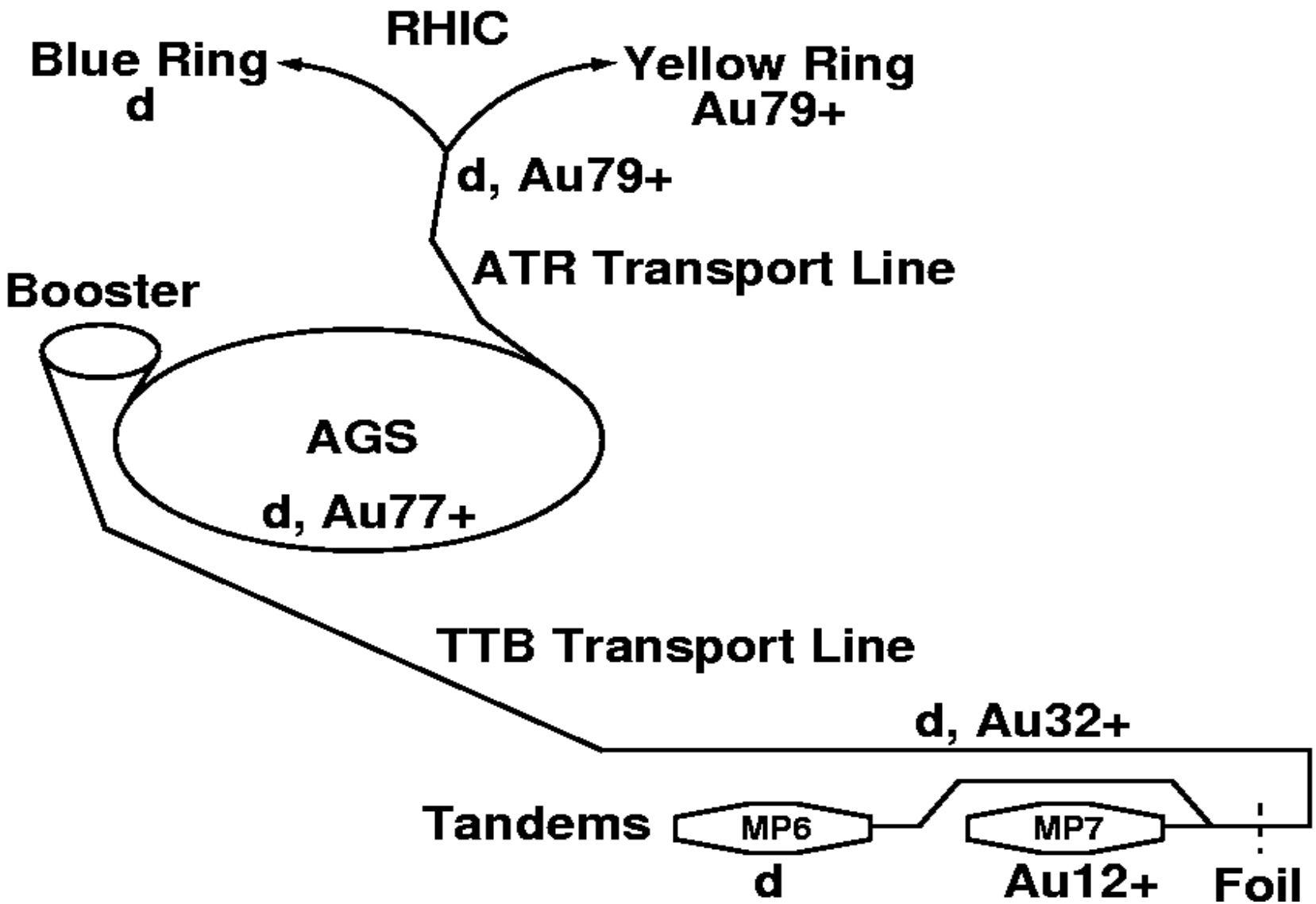
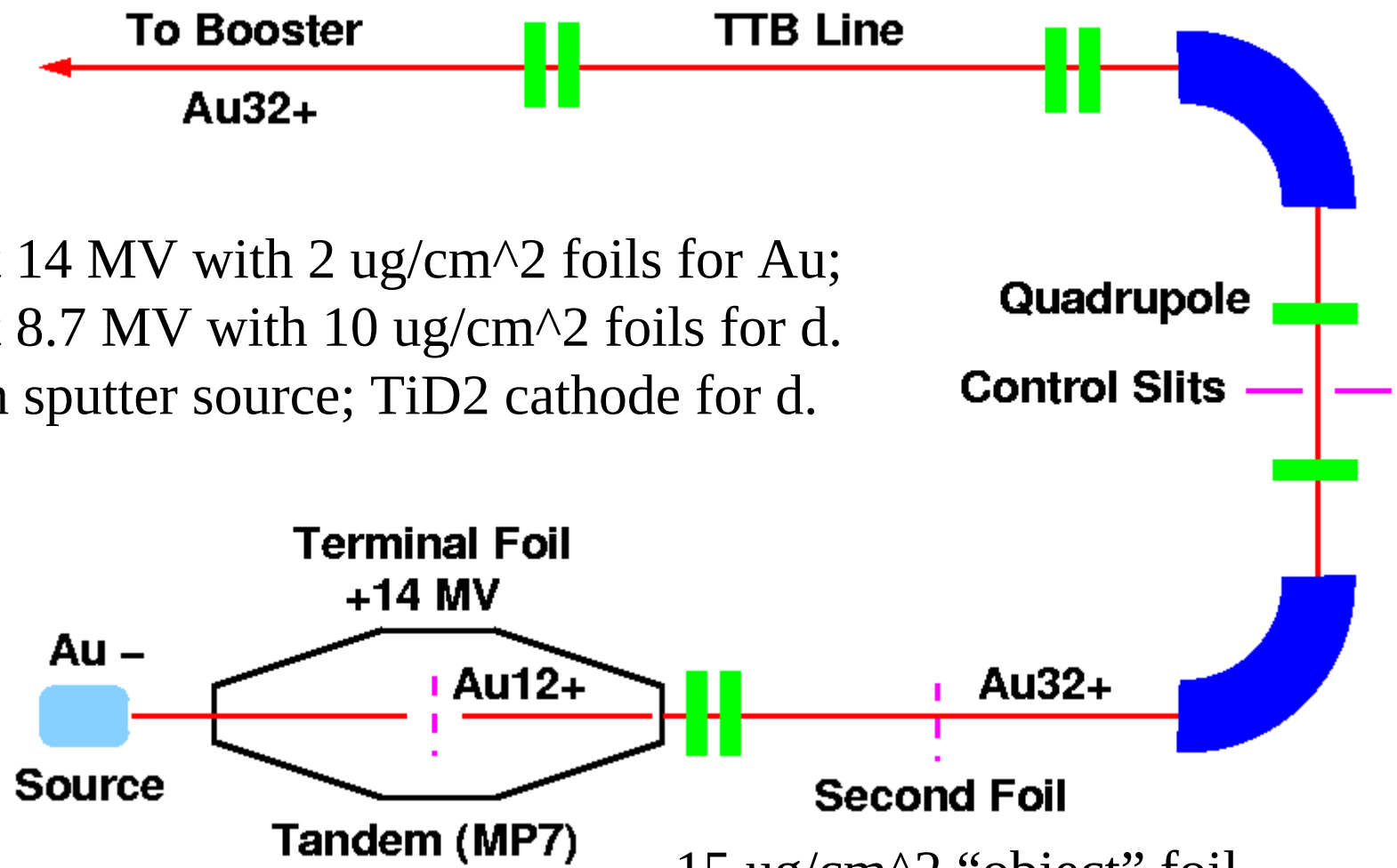
Review of Injector Setup and Performance with Au and d

C. J. Gardner, 10 July 2006

Bird's Eye View of Setup



Tandem Delivery of Ions



MP7 at 14 MV with 2 ug/cm^2 foils for Au;
MP6 at 8.7 MV with 10 ug/cm^2 foils for d.
Cesium sputter source; TiD2 cathode for d.

15 ug/cm^2 “object” foil

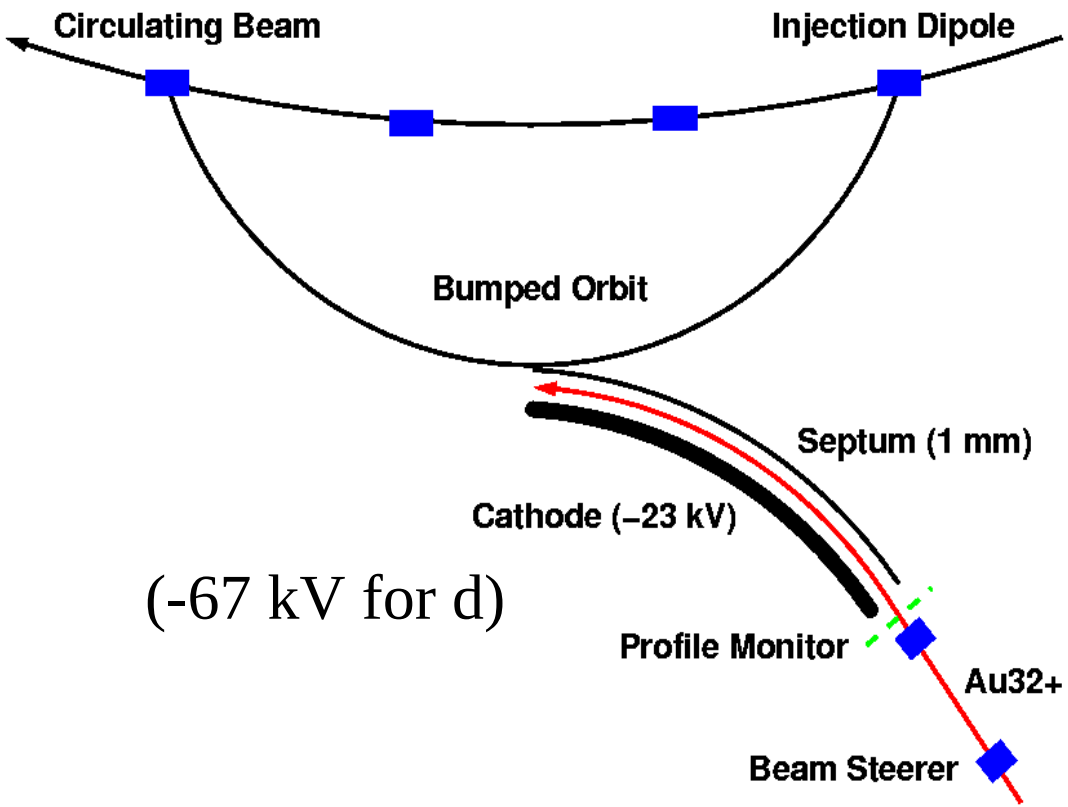
Tandem Performance and Reliability

- 14 MV terminal voltage and 600 terminal foils for delivery of gold; 8.7 MV for deuterons
- Sparks per week at 14 MV?
- Terminal foil consumption: 4 to 6 per day => 100 days for Au; a single foil lasts many days for d
- Up to 4 days to put in a new set of foils, but this has been done in as little as 48 hours
- 100 object foils; each lasts 3 days. Up to 8 hours to put in a new set.

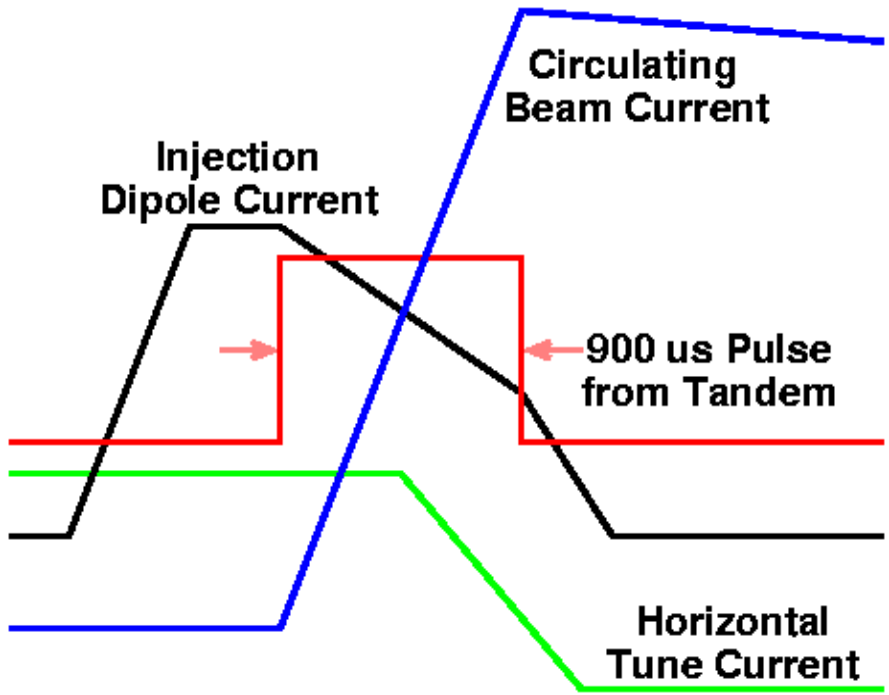
Gold and Deuteron Intensities

- 1000 microsecond pulse width for Au32+ ions; 250 microseconds for deuterons
- TTB transport efficiency 85 to 95%
- Peak of 39 x 10^9 Au32+ ions (in 4 pulses) at end of TTB line; 30 x 10^9 more common
- Peak of 154 x 10^10 deuterons (in 8 pulses) at end of TTB line

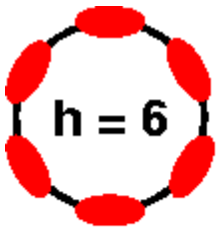
Booster Injection



(-67 kV for d)



Booster Acceleration

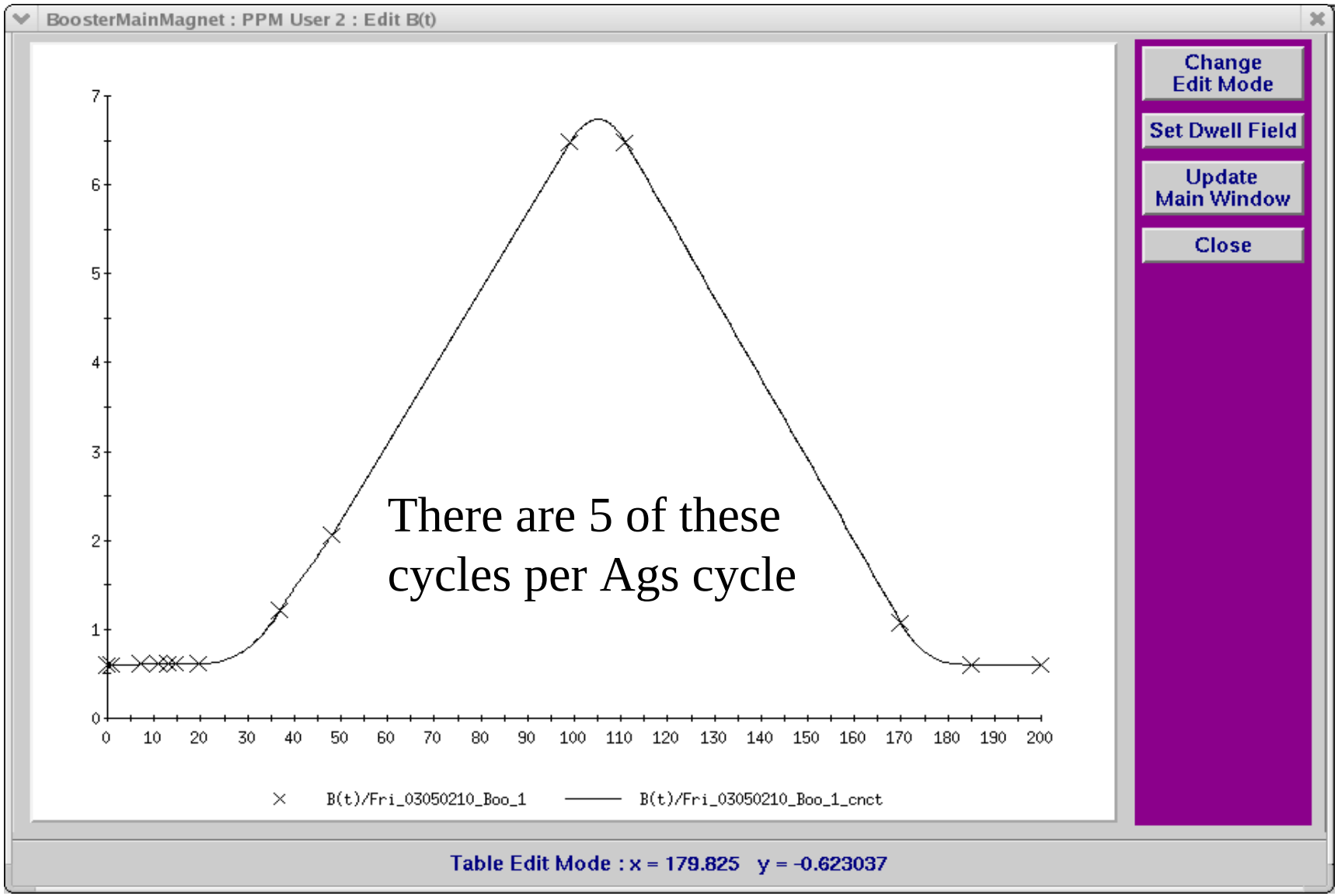


Standard gold setup
0.93 to 101 MeV per nucleon

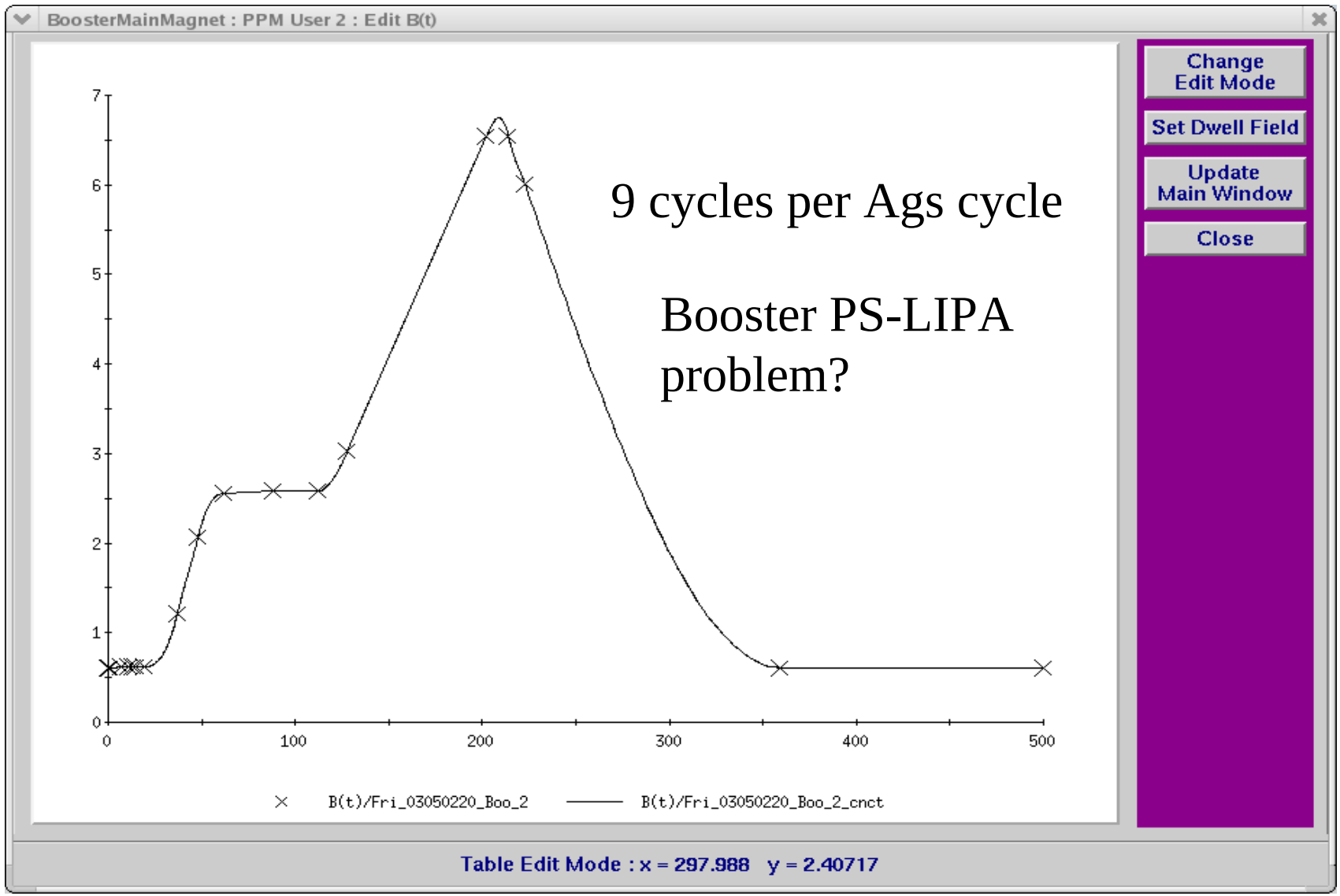
Brennan's new gold setup; doubles the intensity per bunch

Standard deuteron setup
8.7 to 506 MeV per nucleon

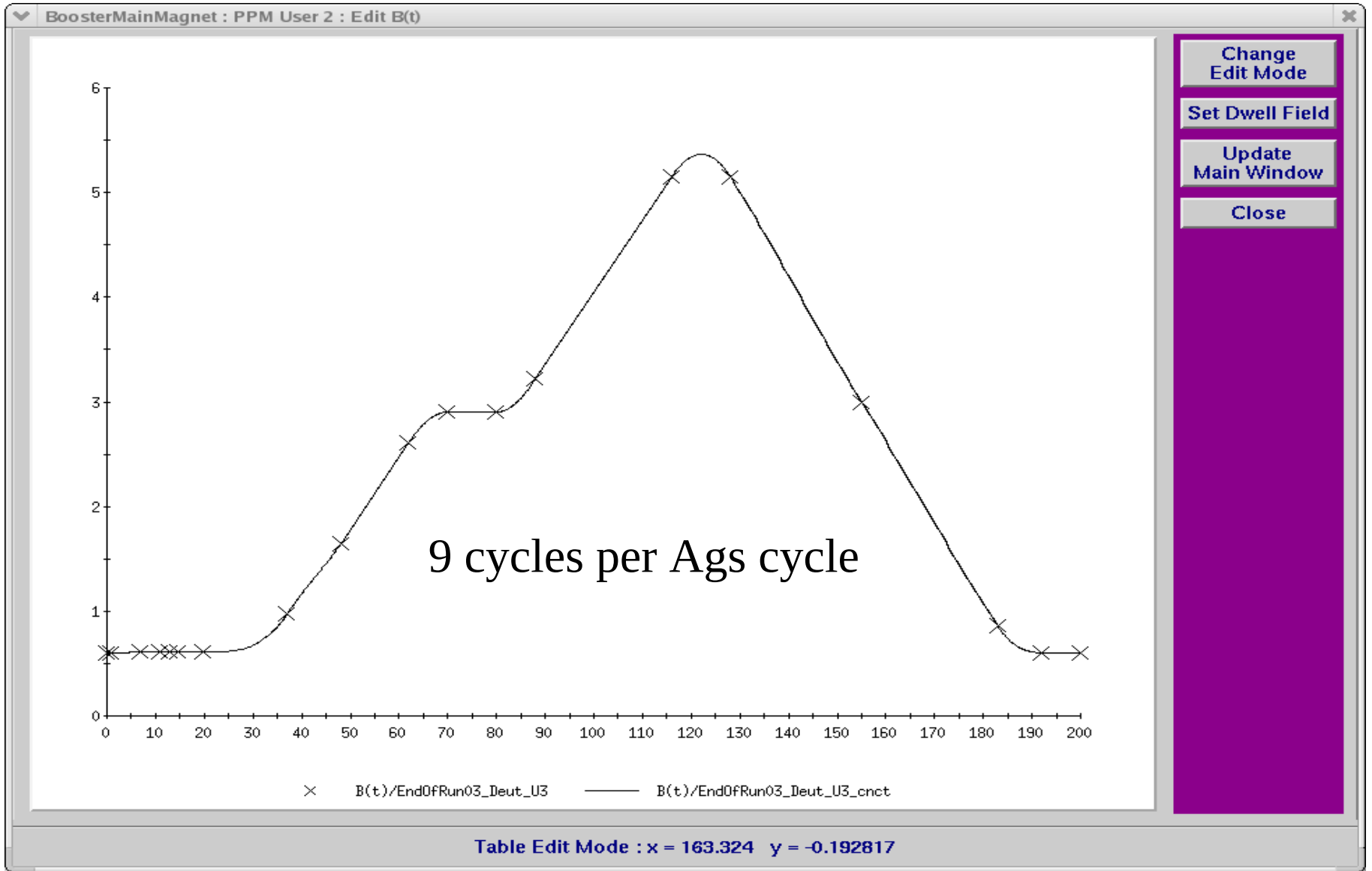
Standard Magnetic Cycle for Gold



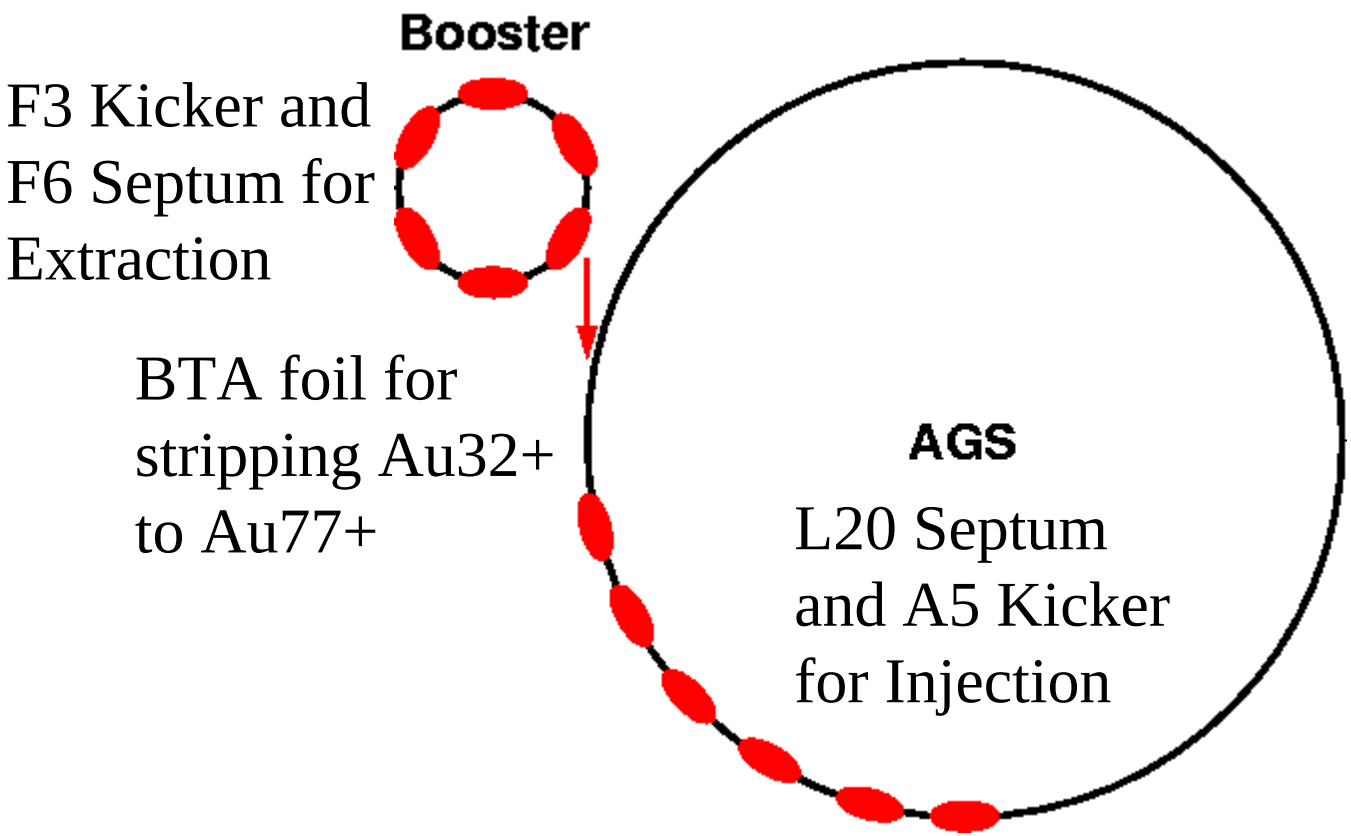
Booster Merge and Squeeze Cycle



Magnetic Cycle for Deuterons

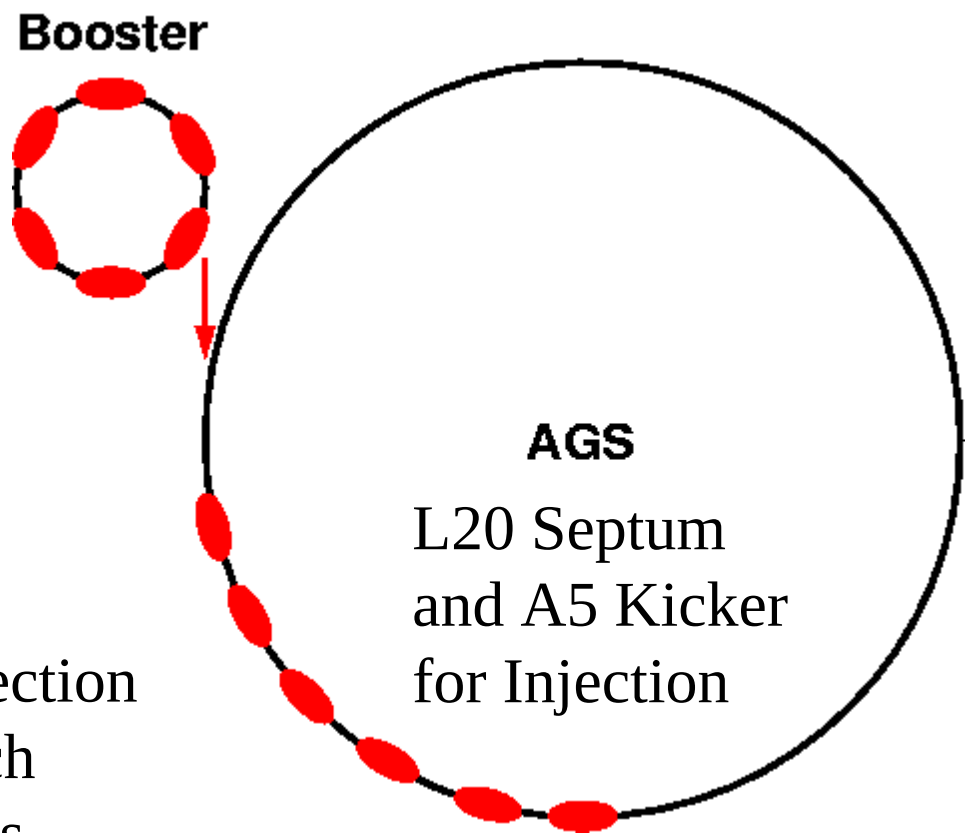


Transfer of one Booster load to AGS



Transfer of one Booster load to AGS

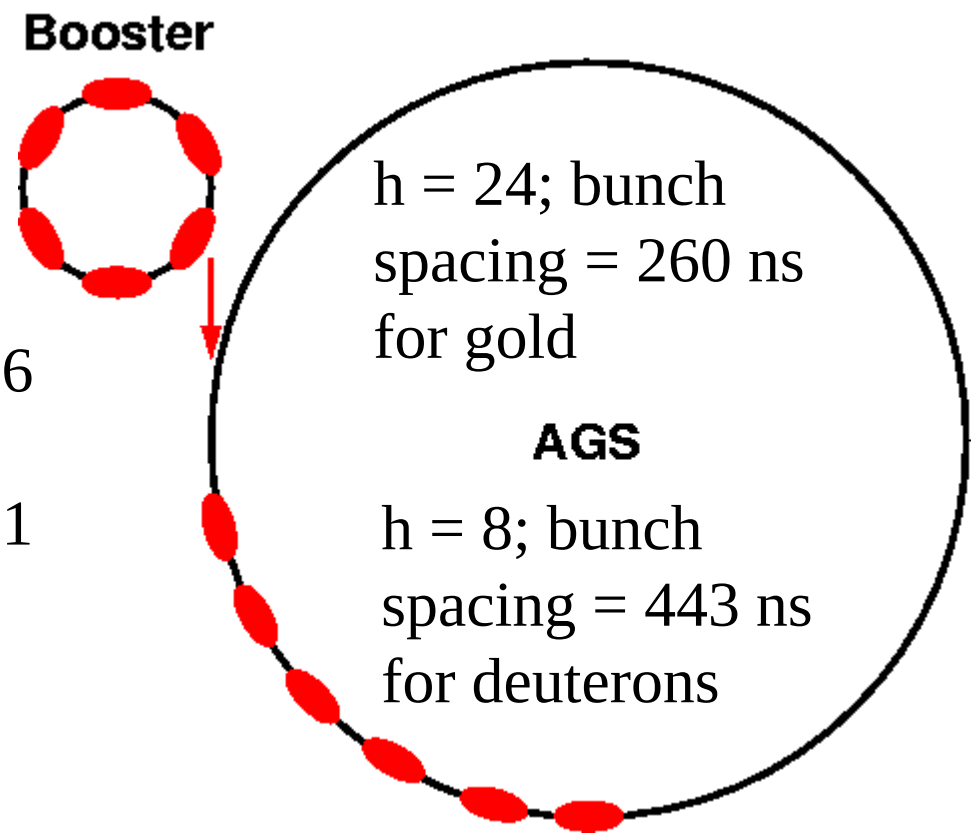
Booster Extraction
Au32+
Brho = 9.14 Tm
Deuteron
Brho = 7.32 Tm



Extraction and Injection devices must switch between 2 rigidities

Ags Injection
Au77+
Brho = 3.72 Tm
Deuteron
Brho = 7.32 Tm

Transfer to AGS

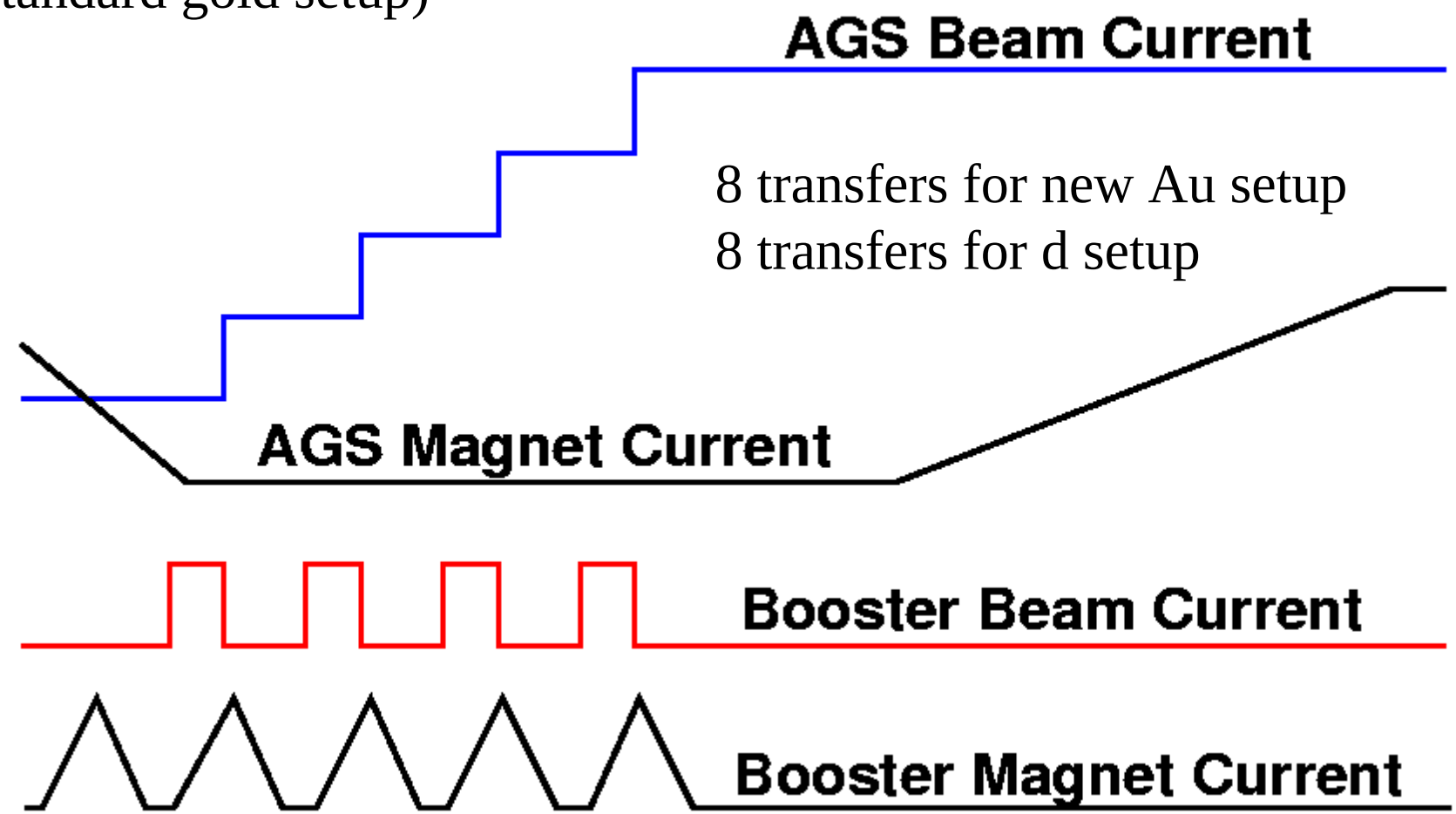


4 transfers of 6 for gold
8 transfers of 1 for deuterons

8 transfers of 3 for Brennan's new gold setup

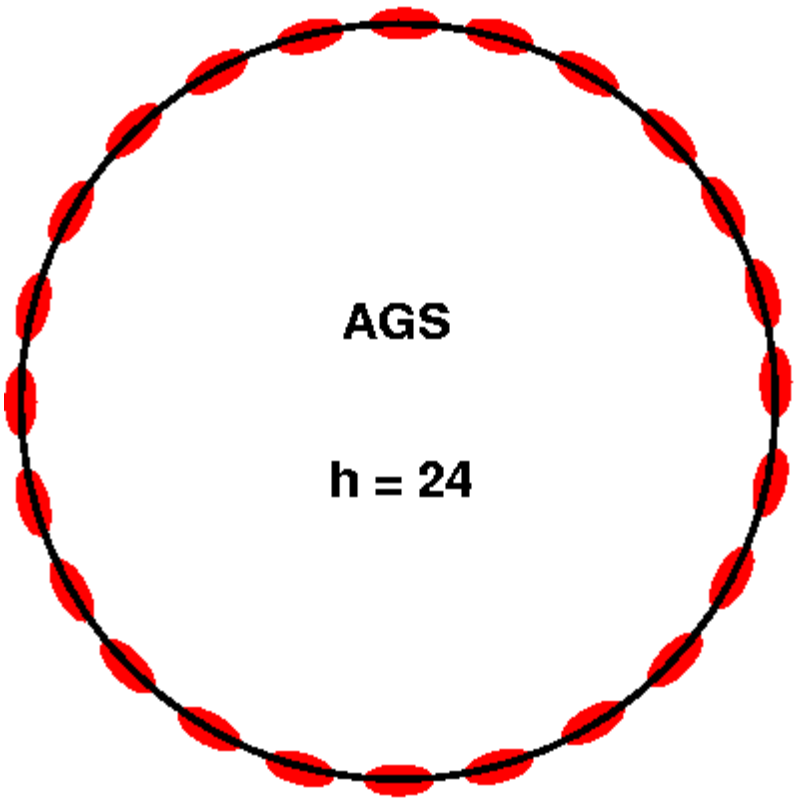
Booster-AGS Timing

(Standard gold setup)

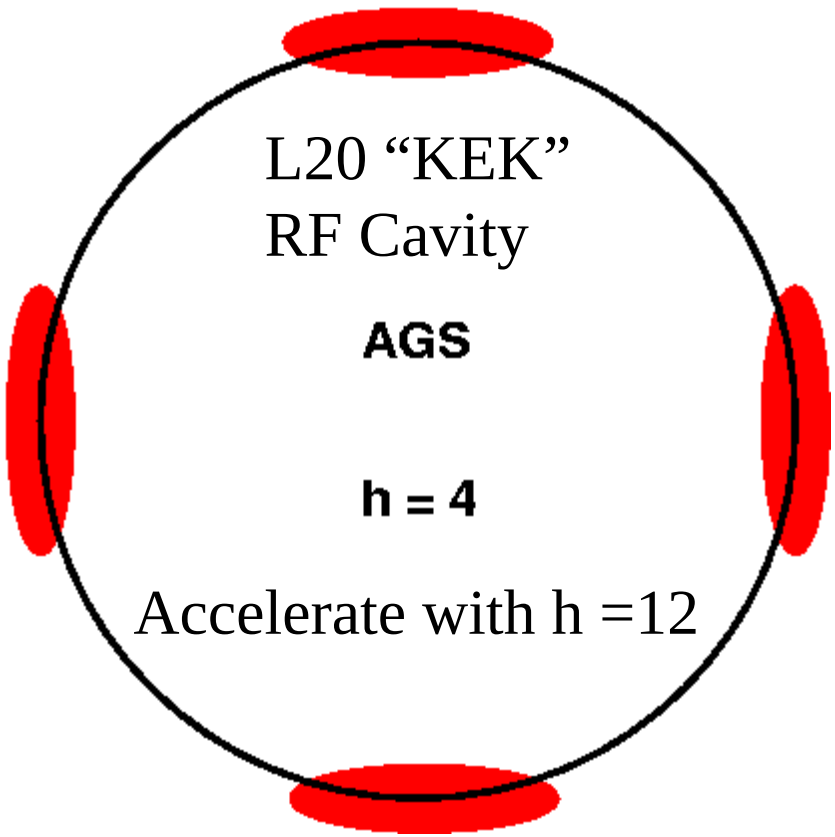


Au De-bunch, and Re-bunch at h = 4

Standard gold setup



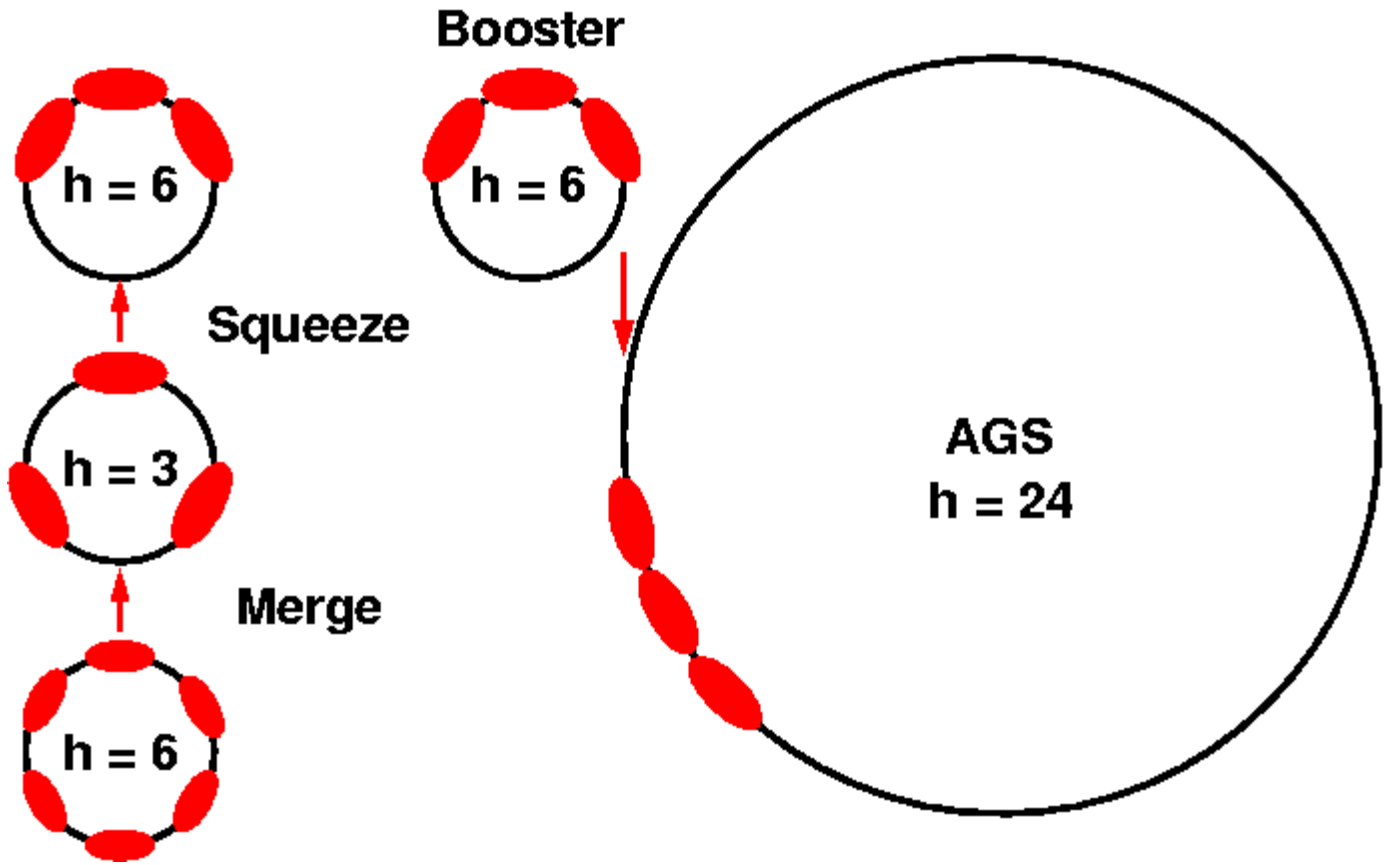
4 Booster loads of 6 bunches
become 4 AGS bunches



Brennan's “Merge and Squeeze”

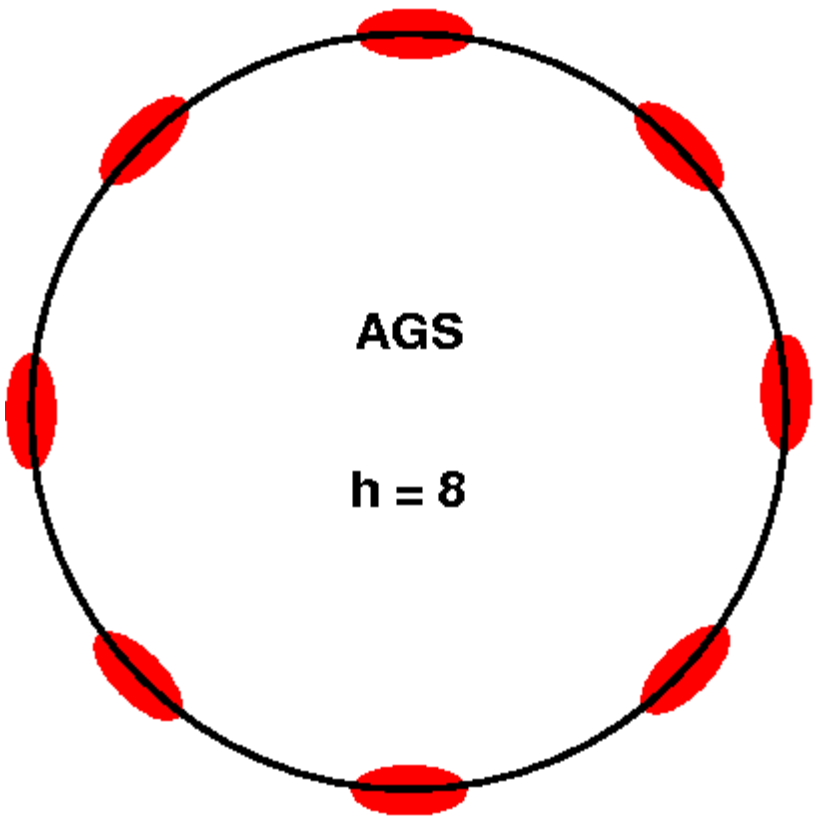
New gold setup

8 Booster loads of 3 bunches become 4 AGS bunches

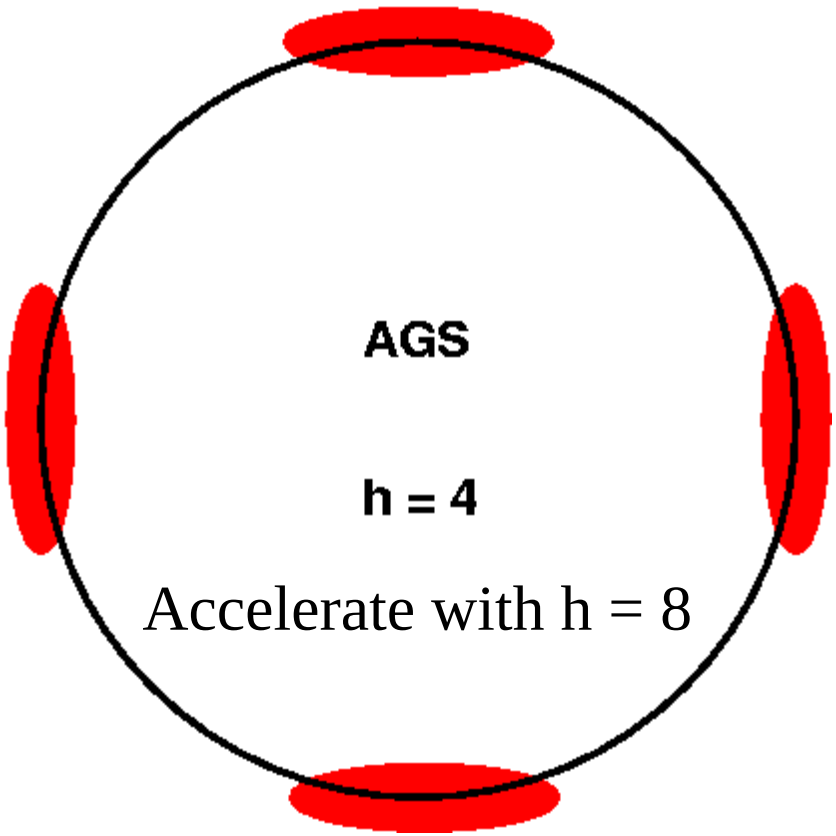


d De-bunch, and Re-bunch at h = 4

Standard deuteron setup



8 Booster loads of 1 bunch
become 4 AGS bunches



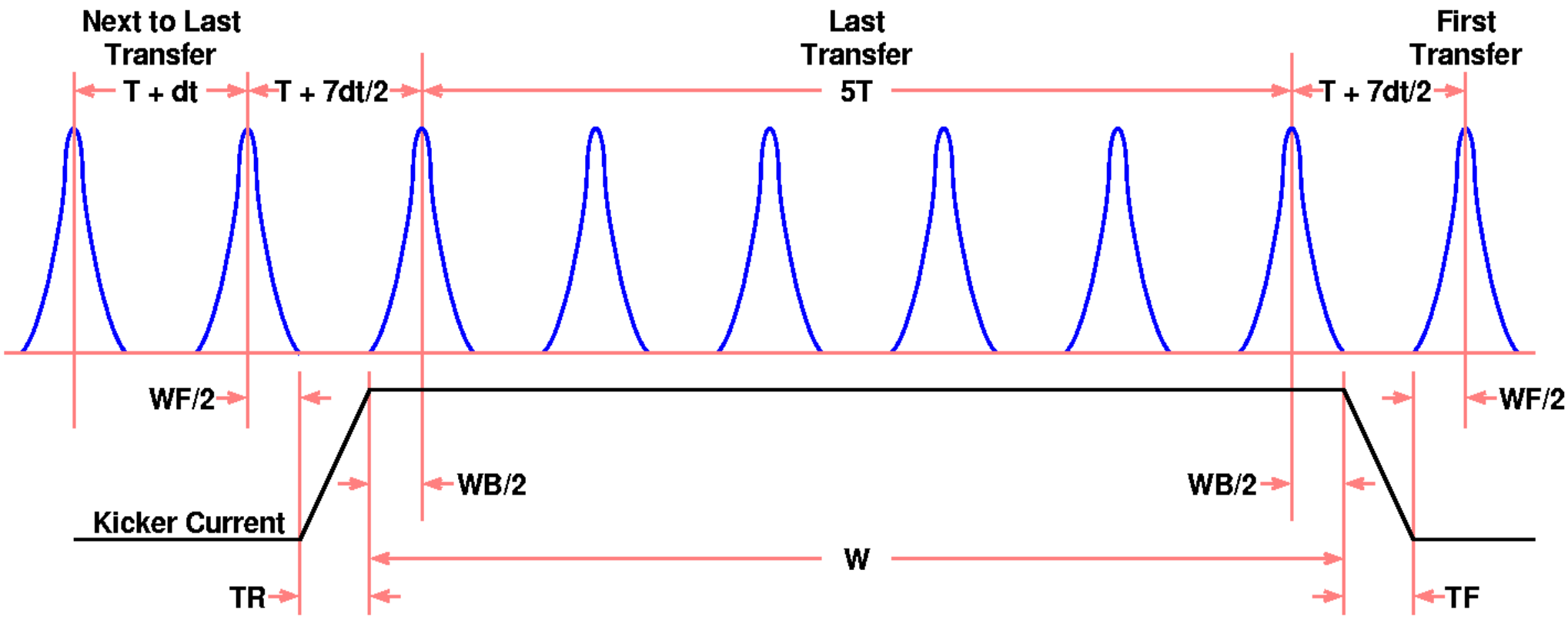
New Ags Merge Scheme to Eliminate De-bunch Re-bunch (Blaskiewicz)

- Eliminate instability due to low dp/p
- Bunch-to-bucket transfer into Ags h = 24 buckets as before
- Bring on harmonics h = 8 and h = 16 to merge 24 bunches into 8
- Bring on harmonic h = 4 to merge the 8 bunches into 4
- For deuterons do 8 to 4 merge?

Ags Extraction, RHIC Injection

- In Ags accelerate to extraction energy on h =12 for Au77+ and h = 8 for deuterons
- Bhro = 90 Tm for Au79+ at RHIC injection (value for gold-on-gold = 81.1137824 Tm)
- Revolution frequency same for Au79+ and deuterons at RHIC injection
- Brho = 92.3381768 Tm for Au77+ at Ags ext
- Brho = 72.711904 Tm for d at Ags ext

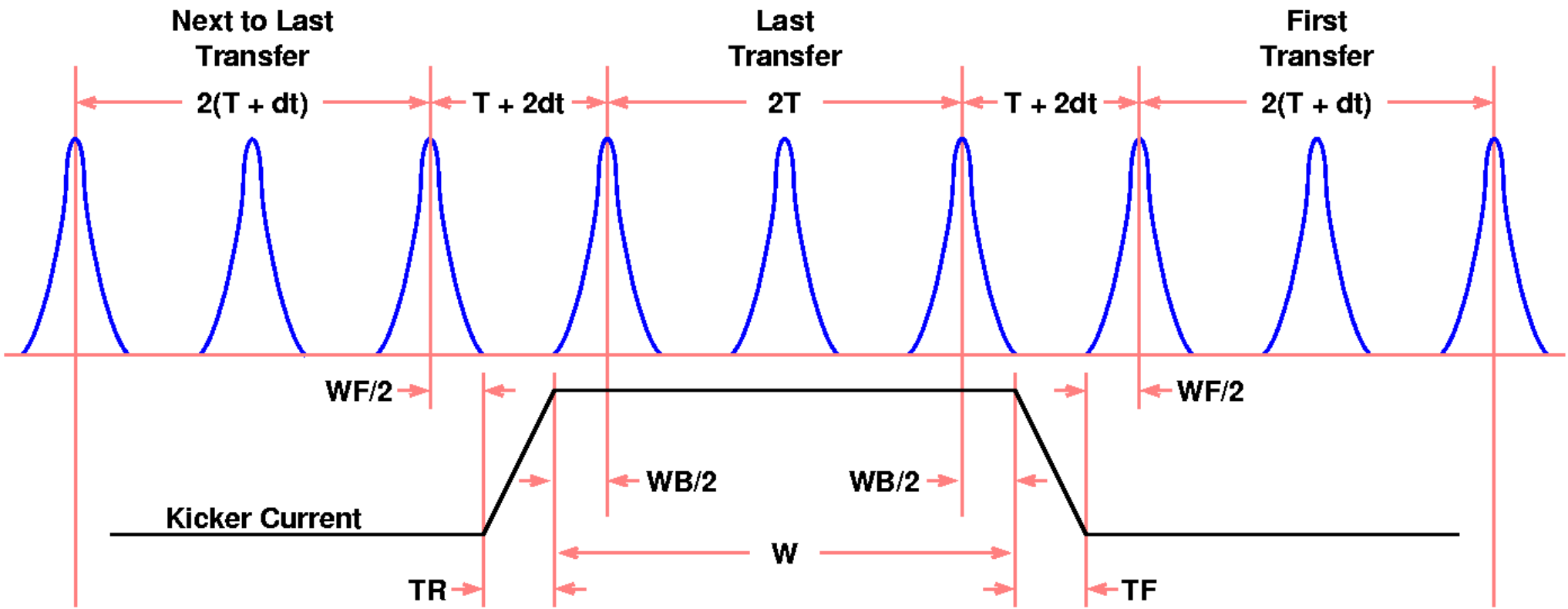
Ags A5 Kicker Timing (Standard Au)



For gold T = 260 ns; T + dt = 265 ns

Need W = 1350 ns; TR = TF < 215 ns

A5 Kick Timing for Brennan Scheme

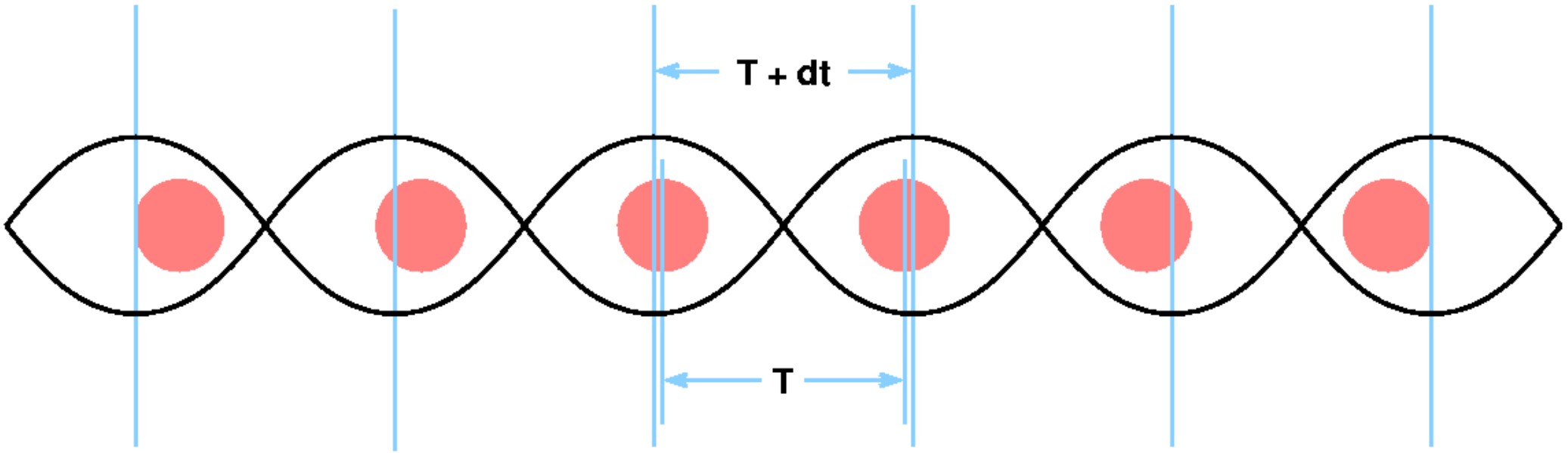


For gold T = 260 ns; T + dt = 265 ns
Need W = 606 ns; TR = TF < 179 ns.
Use for deuterons too (T = 443 ns)

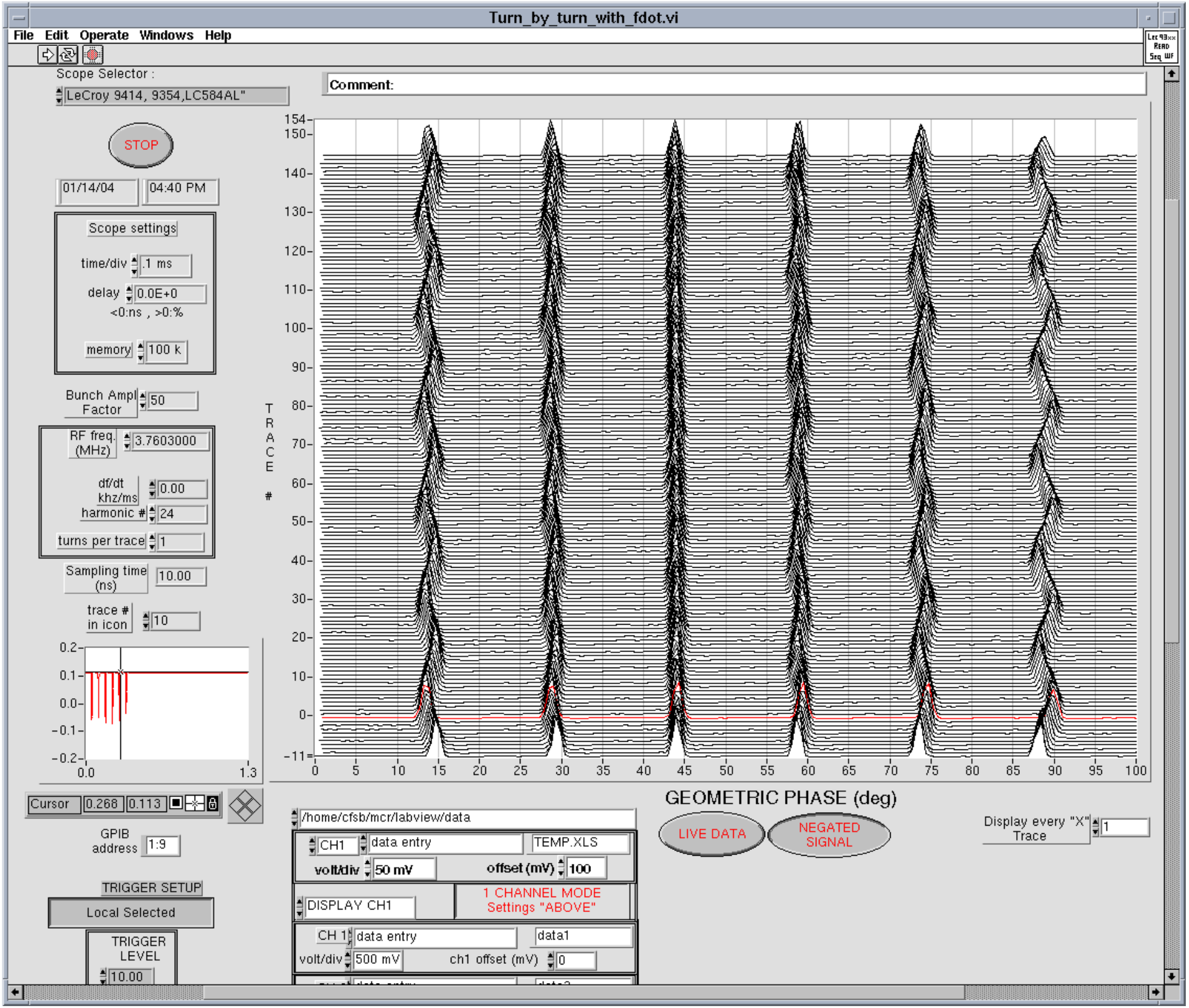
A5 Kick Observations and Questions

- For standard gold scheme, end bunches of each transfer get rattled (pulse not quite wide enough)
- Short pulse mode is used for new scheme; is it wide enough? If not can it be made so?
- Short pulse also used for deuterons; is it too wide for them. This would cause clipping of the last of the 8 bunches transfered.

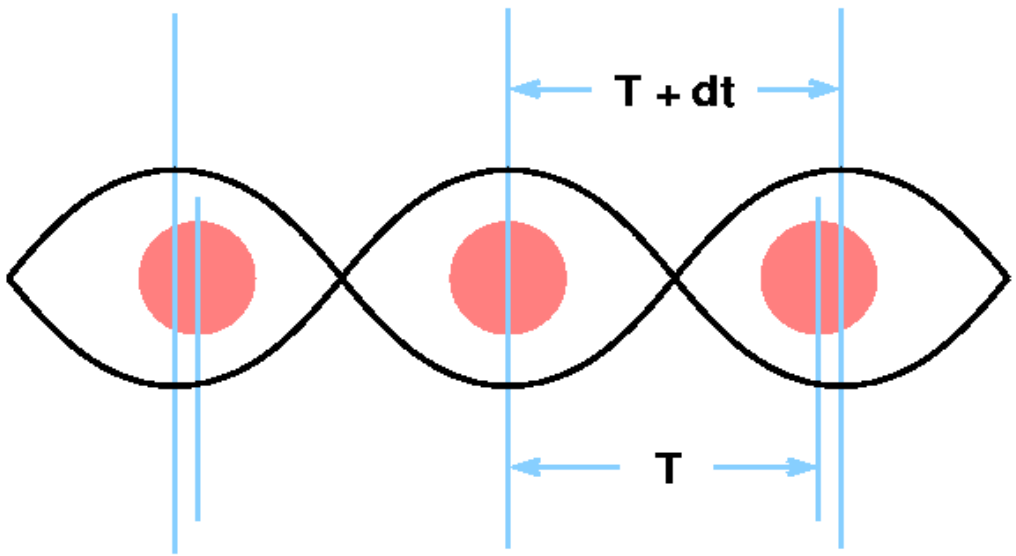
Phase Mismatch (Standard Au setup)



Here T = 260 ns and dt = 5 ns. The displacement between bunch and bucket center is 5 dt/2 in outermost buckets.

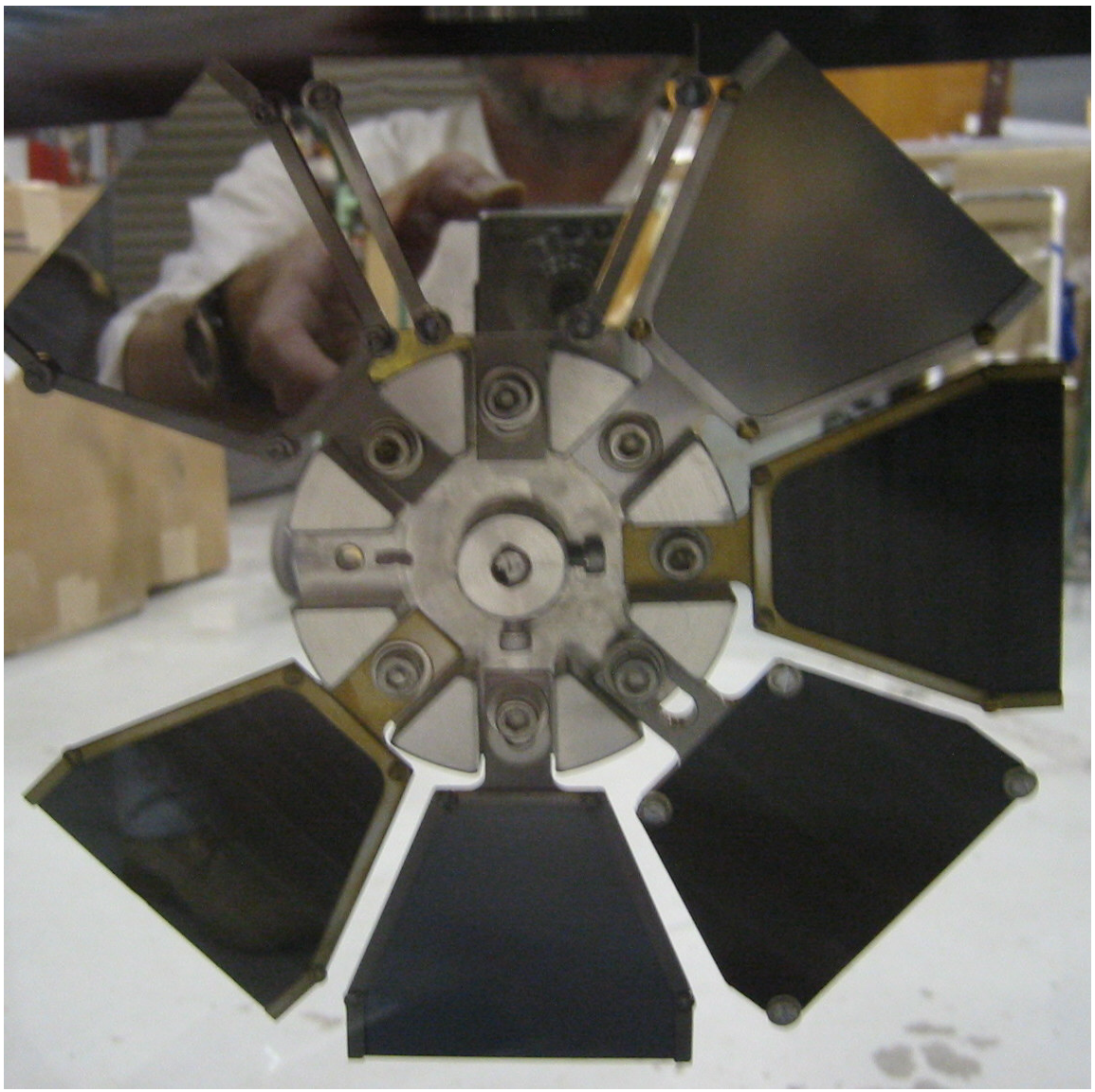

Turn_by_turn_with_fdot.vi
File Edit Operate Windows Help
Scope Selector :
LeCroy 9414, 9354,LC584AL"
Comment:
STOP
01/14/04
04:40 PM
Scope settings
time/div .1 ms
delay 0.0E+0
<0:ns , >0:%
memory 100 k
Bunch Ampl Factor 50
RF freq. (MHz) 3.7603000
df/dt khz/ms 0.00
harmonic # 24
turns per trace 1
Sampling time (ns) 10.00
trace # in icon 10
TRACE #
Cursor 0.268 0.113
GPIB address 1:9
TRIGGER SETUP
Local Selected
TRIGGER LEVEL 10.00
/home/cfsb/mcr/labview/data
CH1 data entry TEMP.XLS
volt/div 50 mV offset (mV) 100
DISPLAY CH1
1 CHANNEL MODE Settings "ABOVE"
CH 1 data entry data1
volt/div 500 mV ch1 offset (mV) 0
GEOMETRIC PHASE (deg)
LIVE DATA
NEGATED SIGNAL
Display every "X" Trace 1

Phase Mismatch (New Au Setup)



Here again T = 260 ns and dt = 5 ns, but now the displacement between bunch and bucket centers is just dt in outer buckets

Present Set of BTA Foils



Set of 7 foils plus 1 blank slot. Each foil can be rotated into the beam. (Beam direction is into the picture)

A new foil changer is to be installed during this summer shutdown. This will make “editing” the foil set much easier.

Present Set of BTA Foils

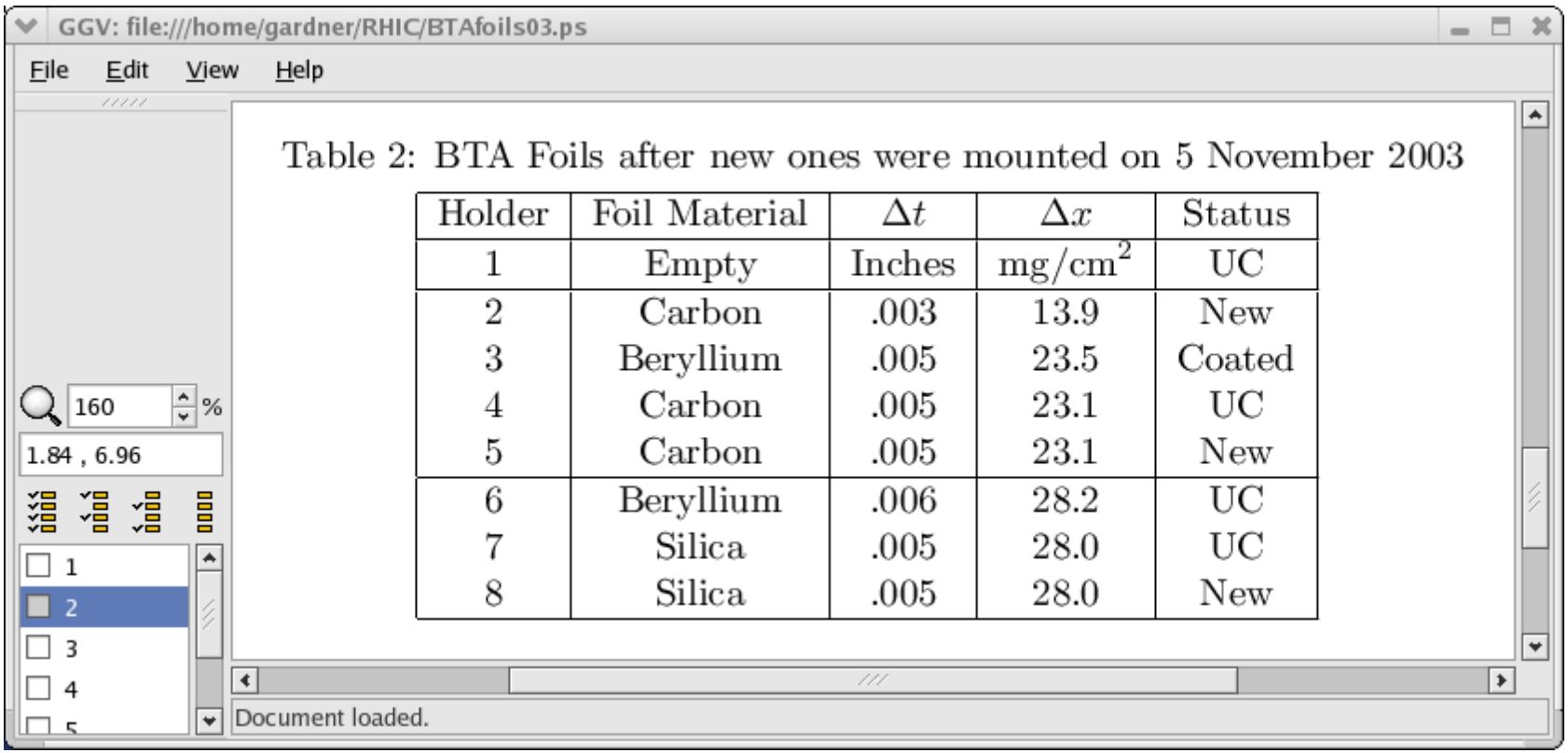
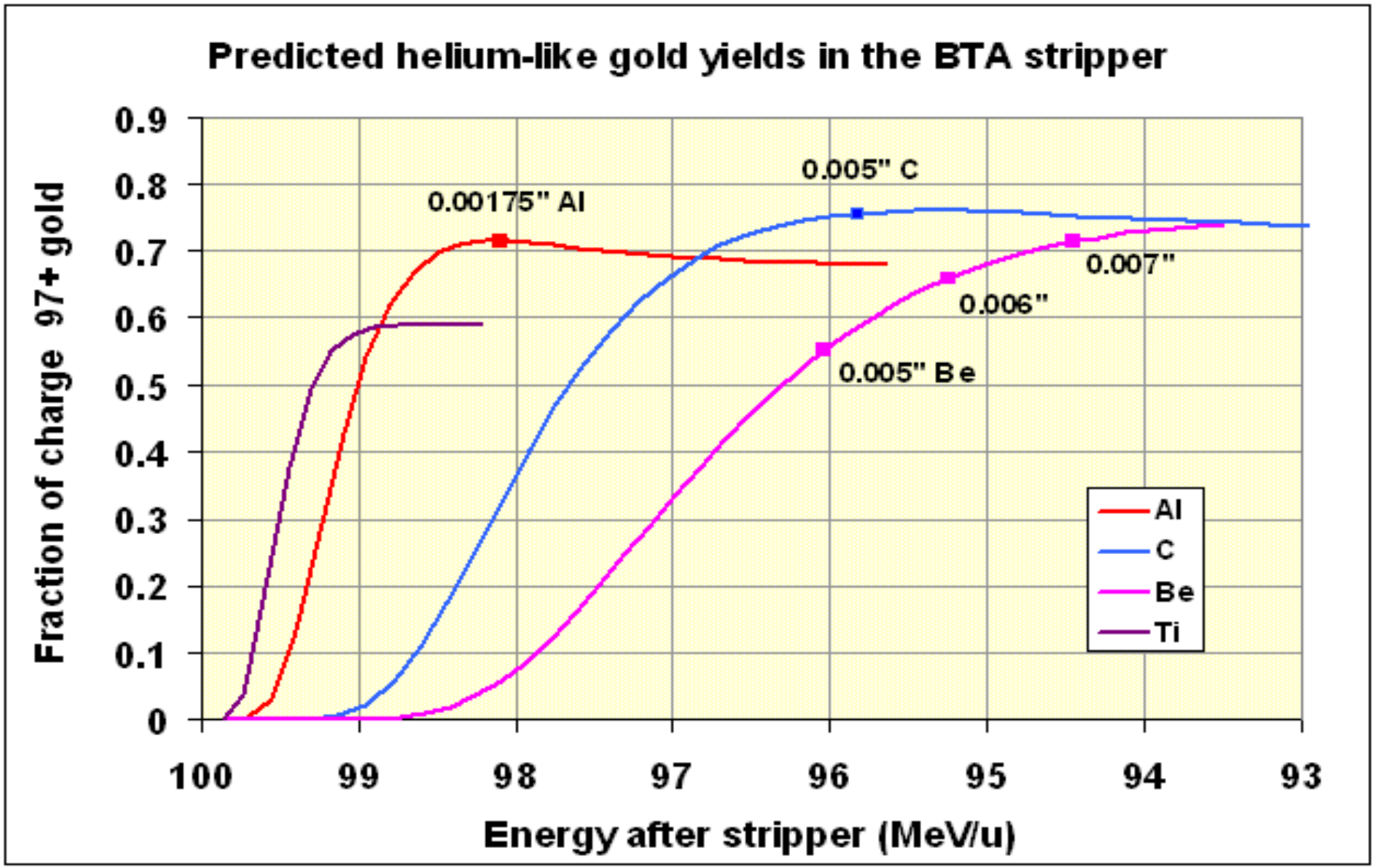


Table 2: BTA Foils after new ones were mounted on 5 November 2003

Holder	Foil Material	Δt	Δx	Status
1	Empty	Inches	mg/cm^2	UC
2	Carbon	.003	13.9	New
3	Beryllium	.005	23.5	Coated
4	Carbon	.005	23.1	UC
5	Carbon	.005	23.1	New
6	Beryllium	.006	28.2	UC
7	Silica	.005	28.0	UC
8	Silica	.005	28.0	New

BTA Foil Calculations (Thieberger)



BTA Foil Calculations (Thieberger)

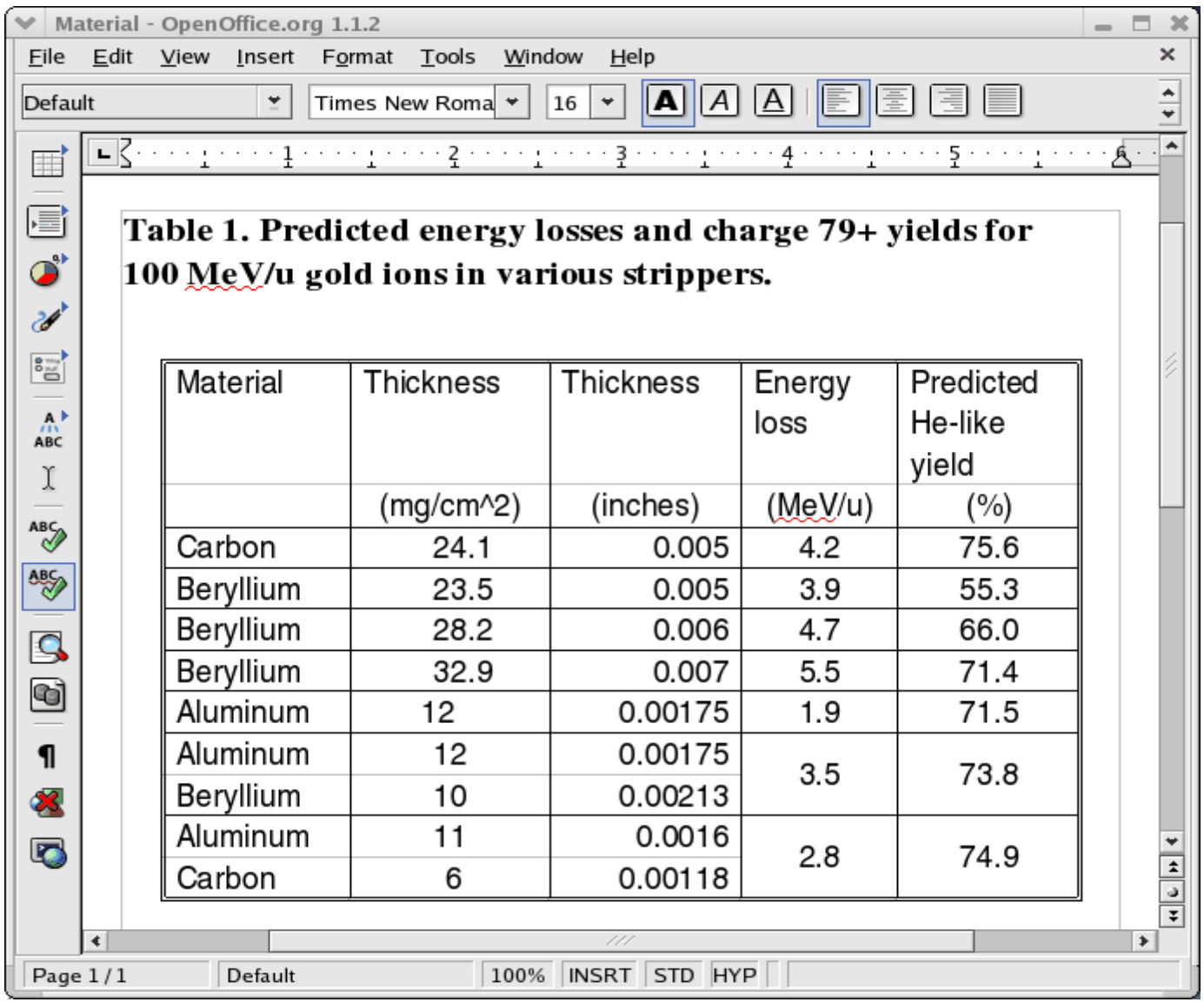


Table 1. Predicted energy losses and charge 79+ yields for 100 MeV/u gold ions in various strippers.

Material	Thickness	Thickness	Energy loss	Predicted He-like yield
	(mg/cm^2)	(inches)	(MeV/u)	(%)
Carbon	24.1	0.005	4.2	75.6
Beryllium	23.5	0.005	3.9	55.3
Beryllium	28.2	0.006	4.7	66.0
Beryllium	32.9	0.007	5.5	71.4
Aluminum	12	0.00175	1.9	71.5
Aluminum	12	0.00175	3.5	73.8
Beryllium	10	0.00213		
Aluminum	11	0.0016	2.8	74.9
Carbon	6	0.00118		

Very uniform foils yield smaller energy spread.

“Glassy” Carbon and aluminum look promising.

Renolds Wrap?

Gold Emittances (longitudinal)

- Single Bunch Emittances for Standard Setup:
- Booster Capture = 0.045/6 eV-s per nucleon
- Booster Extraction = 0.045/6 eV-s per nucleon
- Factor of 4 increase in BTA foil (0.005" C)
- Ags Injection = 0.180/6 eV-s per nucleon
- 50% increase due to filamentation in RF bucket
- Start of Acceleration = 0.270 eV-s per nucleon
- 50% increase during acceleration

Gold Emittances (longitudinal)

- Single Bunch Emittances for New Setup:
- Booster Capture = 0.045/6 eV-s per nucleon
- Factor of 3 increase due to merge and “squeeze”
- Booster Extraction = 0.135/6 eV-s per nucleon
- Factor of 1.6 increase in BTA foil (more uniform)
- Ags Injection = 0.216/6 eV-s per nucleon
- 25% increase due to filamentation in RF bucket
- Start of Acceleration = 0.270 eV-s per nucleon

Deuteron Emittances (longitudinal)

- Single Bunch Emittances for Deuteron Setup
- Booster Capture = 0.080 eV-s per nucleon
- Factor of 3 increase due to merge
- Booster Extraction = 0.240 eV-s per nucleon
- Ags Injection = 0.240 eV-s per nucleon
- Factor of 3 increase due to merge
- Ags Extraction = 0.720 eV-s per nucleon

Transverse Emittances

- Assume Booster H and V acceptances are filled during multi-turn injection
- This gives normalized H and V emittances of 8.3pi and 3.9pi for Au; 25pi and 12pi for d
- Note that BetaGamma at Booster injection is 3 times larger for d than it is for Au
- RHIC wants normalized emittances less than 10pi

Gold Intensities (standard setup)

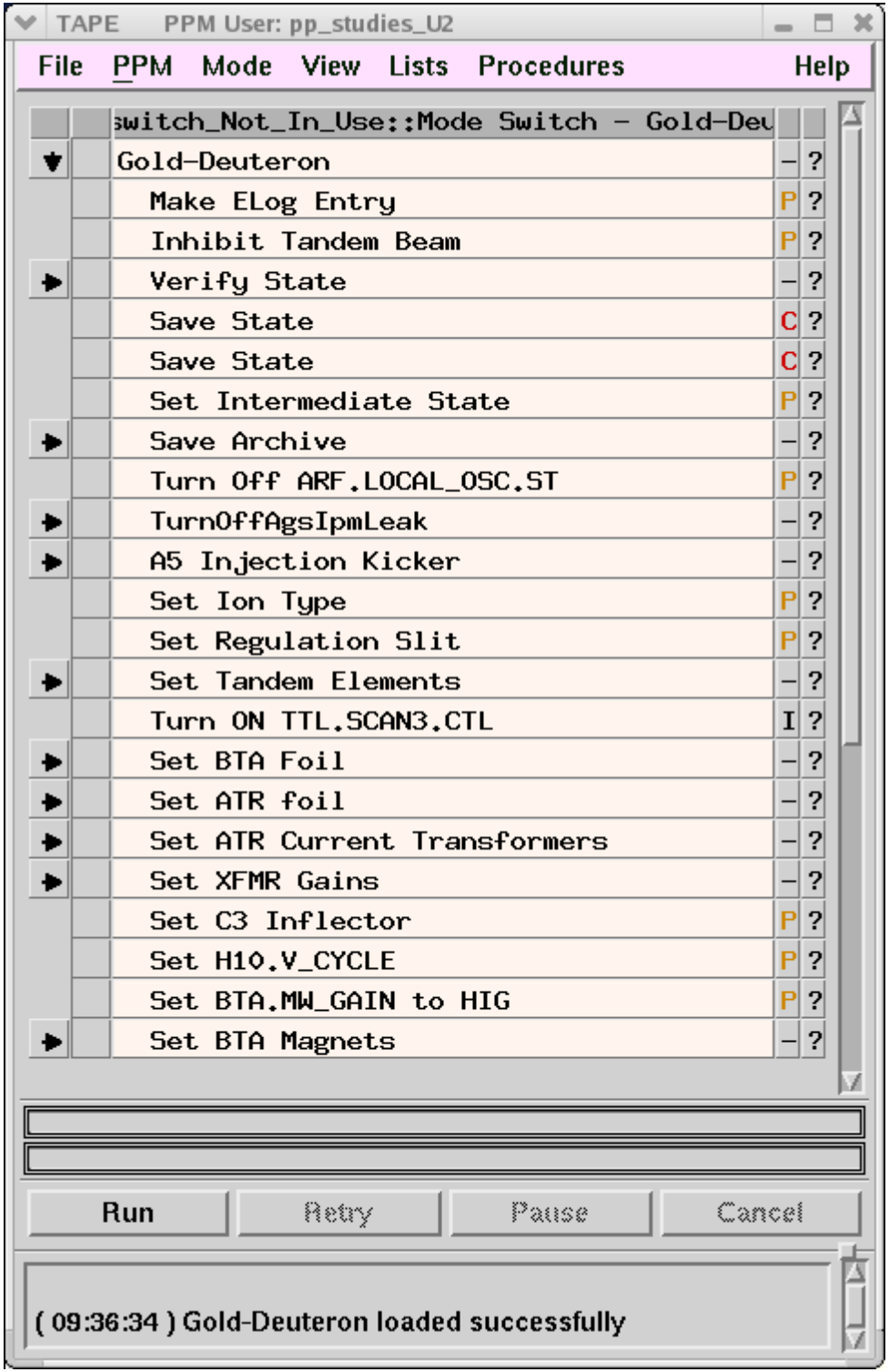
- End of TTB line = 4 x 4.3 x 10^9 (Au32+)
- Booster Injection = 4 x 3.0 x 10^9 {70%}
- Booster Extraction = 4 x 2.4 x 10^9 {80%}
- Ags Injection = 4 x 1.4 x 10^9 (Au77+) {58%}
- Ags Extraction = 4 x 1.3 x 10^9 {93%}

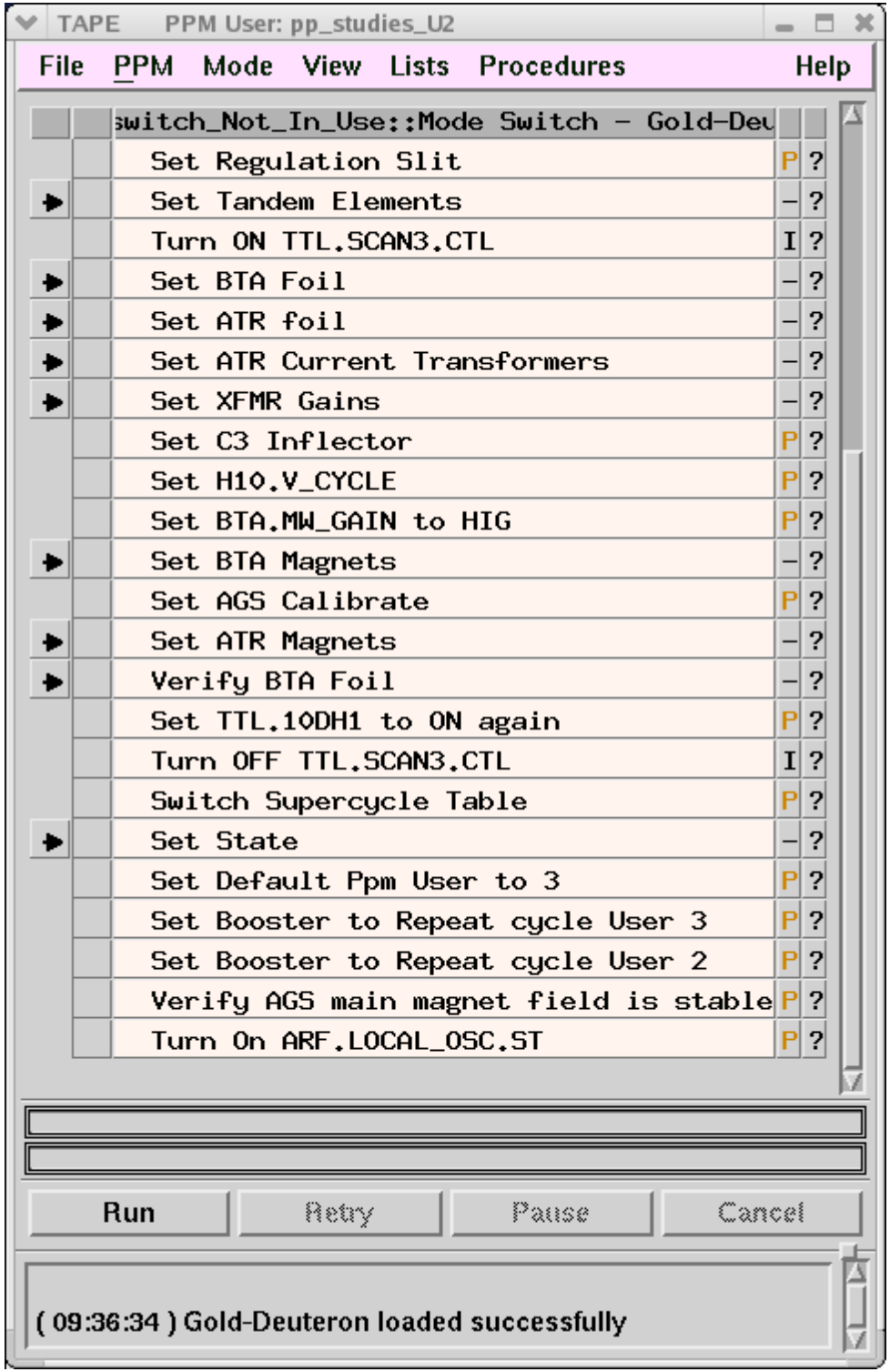
Deuteron Intensities

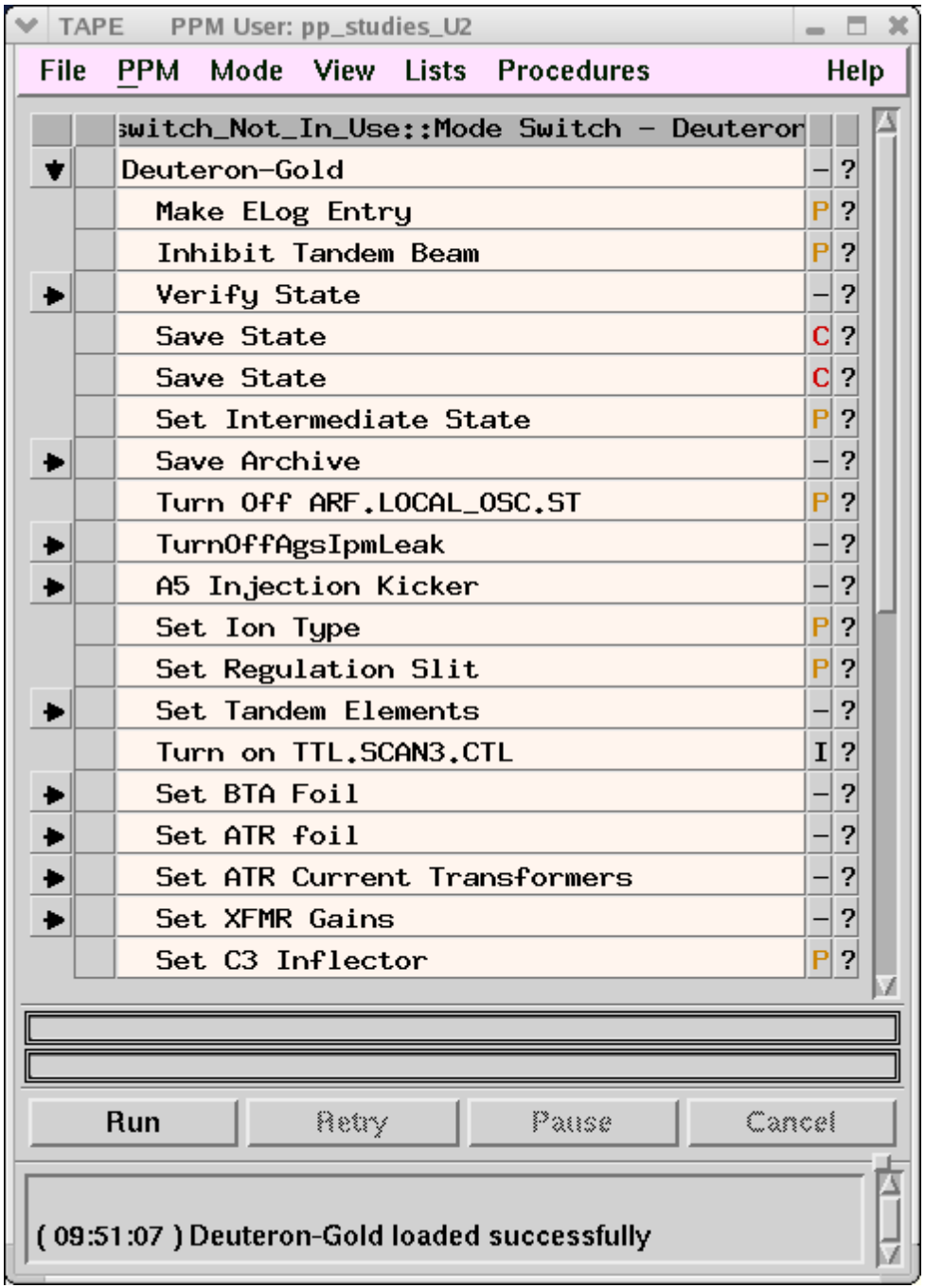
- (Logbook entry 11 March 03)
- End of TTB = 8 x 16 x 10^10 (deuterons)
- Booster Injection = 8 x 8 x 10^10 {50%}
- Booster Extraction = 8 x 7.2 x 10^10 {90%}
- Ags Injection = 8 x 6.7 x 10^10 {93%}
- Ags Extraction = 4 x 13.1 x 10^10 {98%}

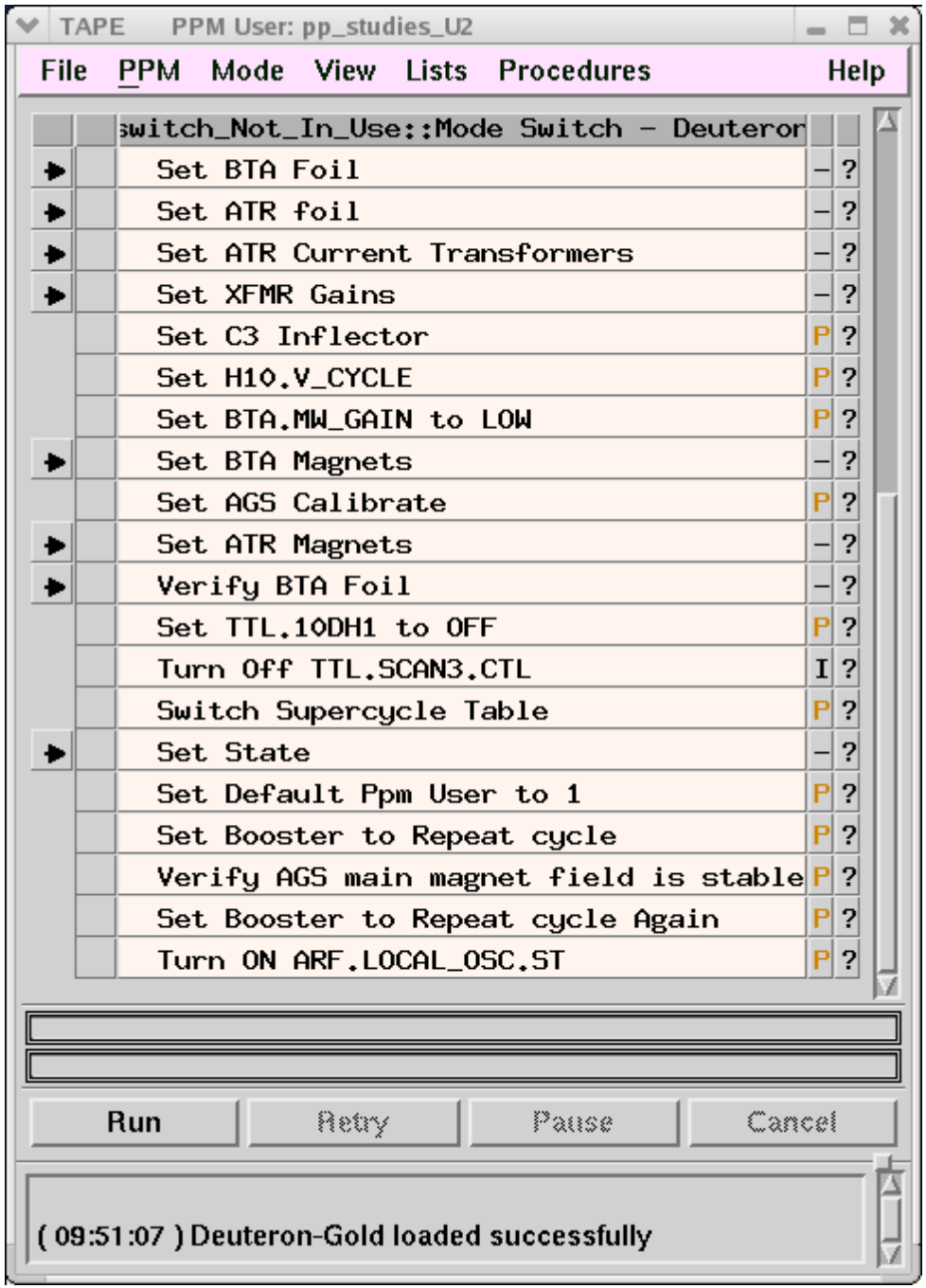
Mode Switching

- Several non-ppm devices must be switched to different operating values when going from gold to deuterons or from deuterons to gold
- The mode switching application shown on the next 2 slides does all this
- Switching time is 3 to 5 minutes


TAPE PPM User: pp_studies_U2
File PPM Mode View Lists Procedures Help
switch_Not_In_Use::Mode Switch - Gold-Deu
Gold-Deuteron
Make ELog Entry
Inhibit Tandem Beam
Verify State
Save State
Save State
Set Intermediate State
Save Archive
Turn Off ARF.LOCAL_OSC.ST
TurnOffAgsIpmLeak
A5 Injection Kicker
Set Ion Type
Set Regulation Slit
Set Tandem Elements
Turn ON TTL.SCAN3.CTL
Set BTA Foil
Set ATR foil
Set ATR Current Transformers
Set XFMR Gains
Set C3 Inflector
Set H10.V_CYCLE
Set BTA.MW_GAIN to HIG
Set BTA Magnets
Run
Retry
Pause
Cancel
(09:36:34) Gold-Deuteron loaded successfully


TAPE PPM User: pp_studies_U2
File PPM Mode View Lists Procedures Help
switch_Not_In_Use::Mode Switch - Gold-Deu
Set Regulation Slit
Set Tandem Elements
Turn ON TTL.SCAN3.CTL
Set BTA Foil
Set ATR foil
Set ATR Current Transformers
Set XFMR Gains
Set C3 Inflector
Set H10.V_CYCLE
Set BTA.MW_GAIN to HIG
Set BTA Magnets
Set AGS Calibrate
Set ATR Magnets
Verify BTA Foil
Set TTL.10DH1 to ON again
Turn OFF TTL.SCAN3.CTL
Switch Supercycle Table
Set State
Set Default Ppm User to 3
Set Booster to Repeat cycle User 3
Set Booster to Repeat cycle User 2
Verify AGS main magnet field is stable
Turn On ARF.LOCAL_OSC.ST
Run
Retry
Pause
Cancel
(09:36:34) Gold-Deuteron loaded successfully


TAPE PPM User: pp_studies_U2
File PPM Mode View Lists Procedures Help
switch_Not_In_Use::Mode Switch - Deuteror
Deuteron-Gold
Make ELog Entry
Inhibit Tandem Beam
Verify State
Save State
Save State
Set Intermediate State
Save Archive
Turn Off ARF.LOCAL_OSC.ST
TurnOffAgsIpmLeak
A5 Injection Kicker
Set Ion Type
Set Regulation Slit
Set Tandem Elements
Turn on TTL.SCAN3.CTL
Set BTA Foil
Set ATR foil
Set ATR Current Transformers
Set XFMR Gains
Set C3 Inflector
Run
Retry
Pause
Cancel
(09:51:07) Deuteron-Gold loaded successfully


TAPE PPM User: pp_studies_U2
File PPM Mode View Lists Procedures Help
switch_Not_In_Use::Mode Switch - Deuteror
Set BTA Foil
Set ATR foil
Set ATR Current Transformers
Set XFMR Gains
Set C3 Inflector
Set H10.V_CYCLE
Set BTA.MW_GAIN to LOW
Set BTA Magnets
Set AGS Calibrate
Set ATR Magnets
Verify BTA Foil
Set TTL.10DH1 to OFF
Turn Off TTL.SCAN3.CTL
Switch Supercycle Table
Set State
Set Default Ppm User to 1
Set Booster to Repeat cycle
Verify AGS main magnet field is stable
Set Booster to Repeat cycle Again
Turn ON ARF.LOCAL_OSC.ST
Run
Retry
Pause
Cancel
(09:51:07) Deuteron-Gold loaded successfully